A
STTR Phase I Project

"Deep Ultra-Violet (DUV) Light Emitting Diodes"

Final Status Report

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Distribution Statement

Deep Ultra-Violet (DUV) Light Emitting Diodes

Problems to Overcome: The main problem to overcome is to develop a commercially and economically viable method to synthesize and process high crystalline quality diamond films for applications such as DUV LEDs and solar-blind detectors.

Scientific Approach: The scientific approach is the homoepitaxial deposition on diamond films on large area (50 -100 mm^2) synthetic Type Ib diamond substrates. Although type Ib diamond substrates have a high nitrogen content (100 -300 ppm), they typically have low density of dislocations which makes them ideal for homoepitaxial film growth. In Phase I, the company will demonstrate high quality, large area crystalline films, while in the Phase II we propose to demonstrate DUV LEDs/detectors using large area diamond manufacturing technology.

Anticipated Payoff: Sinmat Inc. estimates that using the above scientific approach, the cost of making diamond based electron devices can be reduced by a factor of 1000 or more compared to existing technology that uses natural diamond substrates. The unique properties of diamond (large band gap, high thermal conductivity, high carrier mobility and dielectric breakdown) is expected to deliver higher performance devices than expected from other wide band-gap materials (SiC, III-V nitrides, etc.). Sinmat's proposed methodology can significantly enhance the feasibility and commercial viability of diamond based devices.

MDA Importance: The diamond devices (DUV LEDs and detectors) can be used as rugged solar detectors during missile launches and portable solid state lightening sources.

Potential for Tech Transfer: The development of economically feasible manufacturing technology for diamond based electronic devices could be transferred to companies who are actively engaged in fabrication of high frequency and high temperature communication and power devices.

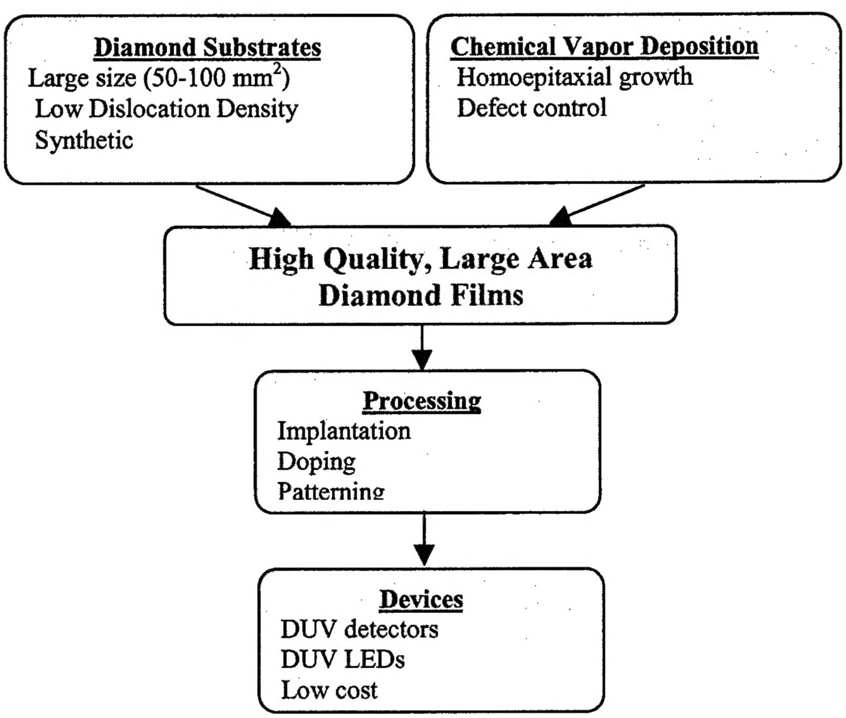


Table A: Scientific approach to economically manufacture diamond based electronic devices

1.0 Phase I Research Objectives and Research Plan (Review)

Sinmat Inc proposes the development of diamond based electronics based on homoepitaxial growth on large Type Ib synthetic diamond substrates. This approach is expected to decrease the cost of manufacturing of diamond based electronics by at least a factor of 1000 compared to the use of natural diamond substrates. Although Type I b diamond substrates have a high nitrogen content (> 200 ppm), they typically have low density of dislocations which makes them ideal for homoepitaxial film growth. The substrates will be obtained from vendors such as Gemesis Corporation or Sumitomo Corporation that have the unique capability to synthesize these large area substrates. In the Phase I of the project, Sinmat will demonstrate the formation of high quality large area diamond films, which are critical for the fabrication of diamond LED's. In the Phase II of this project the fabrication of diamond LED's and other optoelectronics will be investigated.

Phase I Work Plan (Review)

The research plan for this project is as follows: (i) Evaluation of large single crystal diamond substrates, (ii) Diamond CVD growth system set-up and growth, (iii) Evaluation of properties for diamond films, (iv) Phase I report, (v) Patterning and Contact Studies, (vi) Controlled Doping of Diamond Studies, (vii) Diamond LED fabrication, and (viii) Evaluation of diamond LED characteristics. The first four tasks will be initiated and completed in the Phase I of the project, while the last four tasks will be conducted in the Phase II of this project. A time line for the tasks is shown in a sketch below. Each of these research tasks is discussed briefly.

Evaluation of Single Crystal Diamond Substrates: The type Ib diamond substrates will be evaluated for their crystalline quality, impurity content and their dislocation density. Techniques which we plan to adopt include, X-ray topography, X-ray rocking curve, cathodolumiscence, Raman, and FTIR measurements. The X-ray topographic and X-Ray rocking curve measurements will provide information on the dislocation and other defect densities in the crystals. The FTIR will be used to quantify the nitrogen content in the as grown samples. The presence of other defects and other impurities will also be studied by SIMS.

Table 1: Timeline of various Tasks

Phase I	Months				Phase II
	0	2	4	6	
Evaluation of large single crystal diamond substrates	X	X			
Diamond CVD growth system set-up and Growth	X	X	X		
Evaluation of properties for diamond films		X	X	X	
Patterning and Contact Studies					X
Controlled Doping of Diamond Studies					X
Diamond LED fabrication					X
Evaluation of diamond LED characteristics					X

Diamond CVD System Set-Up and Growth: Sinmat possess a metallic hot filament CVD system for the growth of diamond thin films. A microwave CVD system is available at the University of Florida. The system has a base pressure of less than 10^{-7} Torr which is preferred for

high quality epitaxial growth of diamond films. Standard surface preparation procedures will be adopted to clean the diamond surface. Modification in the system will include accurate measurements of temperature during the growth process and use of high purity precursors for the growth. If possible the gas pressure during diamond growth would be kept as low as possible. The effect of the processing conditions such as temperature, gas composition (hydrogen, oxygen and methane), partial pressure, substrate preparation, and substrate quality will be evaluated using standard materials characterization techniques which are available at the University of Florida.

Property Measurements and Correlation: The quality, growth rate and the presence of impurities in the film will be evaluated using standard techniques such as Raman spectroscopy, cathodoluminescence, X-ray diffraction and rocking curve measurements. An important part of the Phase I would be optimization of the quality of the diamond film. Preliminary studies for diamond doping will also be conducted.

Phase I Report and Phase II proposal development: The experimental results will be the basis for the development of the Phase II proposal. If the crystalline quality of the films are excellent, one can expect reproducible doping (both p and n type)of diamond and formation of p-n junctions. Thus the emphasis in Phase I of the project is to maximize the crystal quality of the films. Once the deposition parameters are fixed, correlation of the substrate defect densities with the film quality can be easily determined.

2.0 Summary of Research and Commercialization Accomplishments

The overall goal of the Phase I STTR program is to evaluate the possibility of developing diamond based electronics based on homoepitaxial diamond films on large synthetic Type Ib substrates. Sinmat Inc working with the University of Florida has *successfully completed all the scheduled Phase I research tasks*. There have been several major research accomplishments in the Phase I of this STTR project. A brief summary of the major accomplishments is as follows.

Integration of Large Size Electronic Quality Diamond Substrates for Homoepitaxial Growth. This research has for the first time in this country has demonstrated an integration of a commercially viable diamond substrates with homoepitaxial growth process. Diamond plates of size ranging from 30 mm^2 – 60 mm^2 have been used for homoepitaxial growth of diamond films. Typically, earlier research on homoepitaxial growth have typically used diamond substrates which are approximately 1 –2 mm^2 in size. Thus, by using these substrates, the process has the potential for commercialization of diamond based electronic devices.

Characterization of Diamond Substrates: The research team investigated the use of several techniques to characterize the quality of diamond substrates. These techniques include (i) double crystal X-ray diffraction, (ii) micro Raman, (iii) FTIR, and (iv) SIMS to determine the quality of large synthetic diamond plates.

Extensive Characterization of Homoepitaxial Diamond Films: Detailed materials characterization studies were conducted in this research effort. The results showed that the quality of diamond films was dependent on the quality of the substrate. High quality

homoepitaxial films were grown by the hot filament CVD method; however, some metallic impurities were obtained, which need to be eliminated during the Phase II effort.

Electronic Processing of Diamond: To make diamond based electronics, it is necessary to develop techniques for patterning, doping, and contact formation. Preliminary studies on the patterning were conducted using electron cyclotron resonance (ECR) oxygen plasma. The results showed that diamond the reproducibly etched using and oxygen plasma and high selectivity with silica based films can be obtained. Preliminary ion implantation studies were conducted to determine the possibility of ion implantation based dopant activation.

Investigation of various technologies for fabrication of diamond uv detectors and related devices (LEDs, etc.): In this research period we evaluated the possibility of various large diamond substrates technologies to fabricate diamond based optoelectronics devices. The possibilities include (i) use of special natural diamond substrates (based on A type defects) to synthesize diamond based uv detectors and (ii) homoepitaxial growth based technologies.

Commercialization Accomplishments: Besides technical accomplishments we made significant progress in potential commercialization of this technology. Some of the important accomplishments include.

Establishment of Strong Technical and Commercialization Team: In this research period Sinmat established a strong technical and commercialization team. In the technical area, Sinmat teamed with Gemesis which is the only commercial manufacturer of gem quality diamond stones in the country. Sinmat also established a strong collaboration with Prof. Steve Pearton who is internationally known for electronic device processing and device fabrication in wide band gap semiconductors. In the commercialization side, the company recruited Erik Sanders, who has helped several companies commercialize various technologies.

Significant Reduction in Manufacturing Costs: Sinmat has conducted extensive analysis of the manufacturing costs based on the homoepitaxial growth technology based on synthetic Ib crystals. Based on its estimates, Sinmat predicts that the cost of manufacturing of diamond based electronics can be decreased by at least 3 orders of magnitude if this technology is successfully adopted. The reduced cost is due to (i) use of larger substrates, (ii) higher process reproducibility of synthetic substrates, (iii) lower cost of synthetic substrates, and (iv) large device and die integration capability.

3.0 Phase I STTR Research

The results from the scheduled tasks are described in detail below.

Task I: Fabrication and Evaluation of Large Single Crystal Diamond Substrates.

A major task of this research effort is the fabrication and evaluation of large diamond plates. Typically the natural diamonds grown by high pressure and high temperature techniques is in the form of faceted crystals of various sizes. A typical example of diamond crystals (manufactured by Gemesis or Sumitomo) is shown in Figure 1(a). The figure shows that the faceted as grown diamond crystals are typically 5 – 8 mm in dimensions. The faceted crystals have to be cleaved and polished/cleaned to form diamond plates. Sinmat has been working with various companies to fabricate diamond plates. Examples of a (100) and (111) diamond plates are shown in Figure 1(b). The diamond is essentially flat and cleaved/cleaned to expose the crystallographic surface. The typical areas of the largest plates, which can be presently obtained by Sinmat, vary from 30 mm square to 75 mm square.

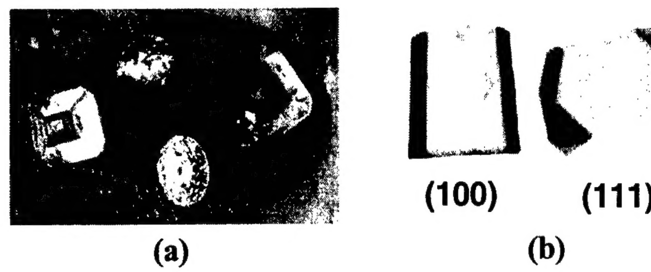


Figure 1: (a) Single crystal diamond grown by Gemesis Corporation. (b) Optical micrograph of (100) and (111) diamond plates obtained from synthetic crystals. The dimension of the plates varies from 5 to 7 mm.

The synthetic diamond plates used in this research can be classified into type Ib crystals which typically has some nitrogen based impurities. The nature of diamond impurities can be determined using the FTIR spectra. Figures 2(a) and (b) show and contrast the FTIR spectra obtained from dopant-free rare, natural Type II a diamonds and from synthetic Type Ib diamonds used in this research effort. Figure 2(a) shows the FTIR spectra from a genuine impurity-free diamond (Type IIa) which is characterized by second and third harmonic lattice vibrations (wave numbers 1500 to 2500 cm^{-1}). Such crystals are extremely rare and even if available are in very small size (1mm or less). Figure 2(b) shows the FTIR spectra from a typical Type Ib diamond. The extra FTIR features in type Ib compared to type IIa are due to incorporation of impurities such as nitrogen in the crystal. The introduction of nitrogen into the lattice leads to a local breakdown of the O symmetry, and absorption in one phonon region is no longer forbidden. The absorption characteristics in the wave number interval 1000- 1400 cm^{-1} depends on the state of aggregation of the nitrogen atoms. Thus, by evaluating

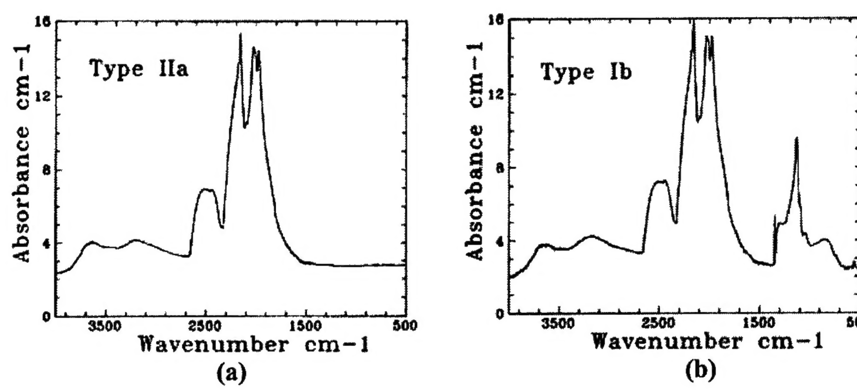


Figure 2: Typical FTIR spectra obtained from (a) very pure type IIa and (b) nitrogen doped type Ib diamond.

the sharpness and strength of the FTIR peaks at 1000 –1400 cm^{-1} regions, the concentration of the nitrogen impurities in the crystals can be predicted.

Figure 3 shows the FTIR absorbance spectra obtained from 2 different diamond plates. The FTIR spectra show the typical characteristics of Type Ib synthetic diamond substrates. Nitrogen is a typical impurity used in the Type Ib diamonds. The nitrogen in the Type Ib diamond is in form of non-aggregates, giving rise to a light yellow color. By controlling the growth conditions the amount of nitrogen impurities can be controlled. This figure clearly shows that the amount of nitrogen impurity varies from different samples. The nitrogen center is a deep donor with ionization energy of about 2 eV. Thus, by itself the Type Ib substrate may not be suitable for diamond electronics. However, by growing a diamond epitaxial film, the structures become more suitable for diamond electronics. The diamond substrates were also characterized by SIMS techniques to quantify the amount of nitrogen in the bulk plates. Typical concentration of nitrogen of $< 3.5*10^{19}$ were obtained from these plates (see Table 2).

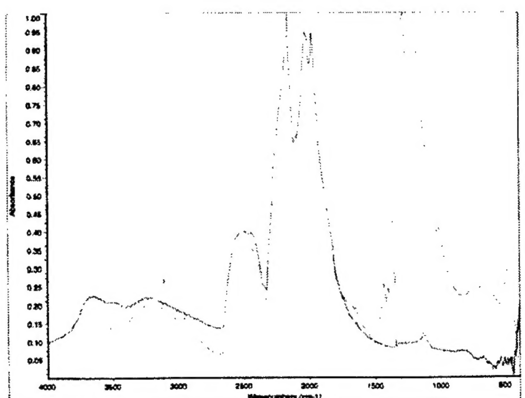


Figure 3: FTIR spectra from two different diamond plates. The variation in the spectra is due to varying nitrogen content in the samples.

Table 2: The typical concentration of impurities obtained in diamond plates using SIMS measurements

Element	Concentration of Impurities determined by SIMS experiments ($\#/cm^3$)
H	$7.0*10^{18} - 1.3*10^{19}$
N	$0.5*10^{19} - 3.5*10^{19}$
O	$< 2*10^{18}$
Si	$< 2*10^{16}$
P	$< 2*10^{16}$

The diamond plates were also characterized by Raman and X-ray diffraction measurements. The X-ray diffraction can provide information on the misorientation and the defectivity of the diamond substrates, since this measurement is sensitive to both the dispersion in the lattice constant and the orientation of the crystalline material. Both phi curves and the rocking curves were obtained from these samples. A rocking curve is a plot of the diffracted x-

ray intensity around the Bragg angle of a particular crystallographic orientation. Figure 4(a) and 4(b) show the rocking curve and the phi scan from Type Ib diamond substrates. The figure clearly shows the 3-fold symmetry of the (111) phi scan. The full width at half maximum of the (111) peaks is approximately 80 arc-seconds attesting to the high quality of diamond plates. It should be noted the typically FWHM of the high quality natural diamond substrates are typically much lower (30 –50 arc-seconds) due to a lower amount of impurities and domain structure formation.

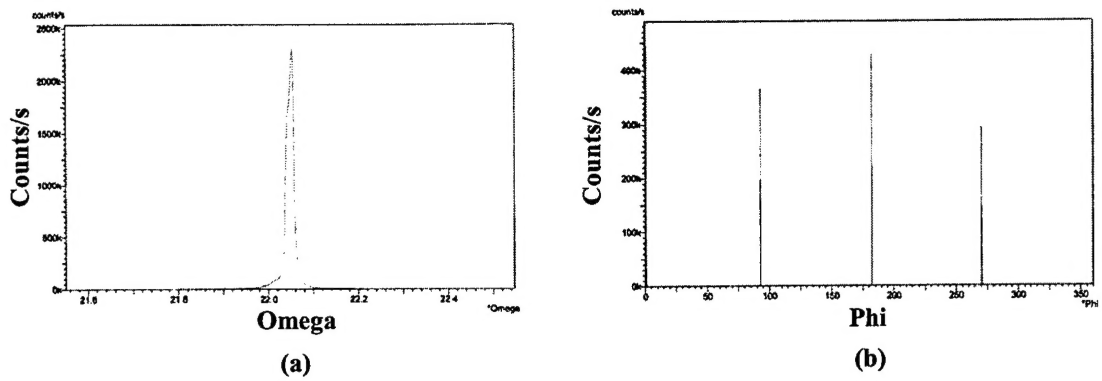


Figure 4: (111) rocking curve (a) and phi scan (b) obtained from a diamond substrate plate.

Task II. Evaluation of Heteroepitaxial Diamond Film Growth:

Heteroepitaxial diamond films were synthesized using the hot filament CVD process. For the hot filament CVD process, a wire filament (typically tungsten or Ta) is heated to 1800 –2400 C for the purpose of dissociating gas molecules to reactive atomic and molecular species. The gases used were a combination of methane (0.1 to 4%), oxygen and hydrogen. A schematic diagram of the chamber is shown in Figure 5. The approximate pressure during the deposition process is approximately 20 to 50 Torr. The substrate temperature was maintained between 950 and 1000 °C during the deposition process. The thickness of the films deposited was varied from 1 micron to approximately 10 microns, with the deposition rates typically in the range of 1 micron/hr. Various parameters were varied during the homoepitaxial growth including gas composition, substrate temperature, and gas pressure and deposition time. The epitaxial quality of the films was analyzed as a function of the various variables. The microstructural quality of the films was determined by X-ray diffraction and Raman spectra measurements.

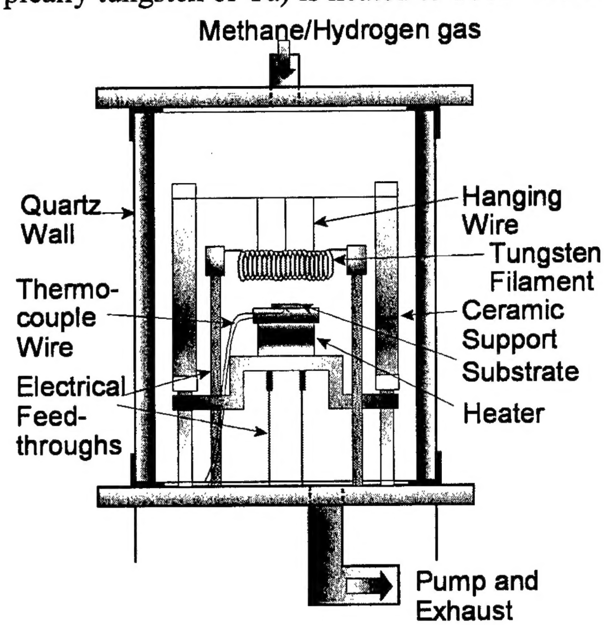
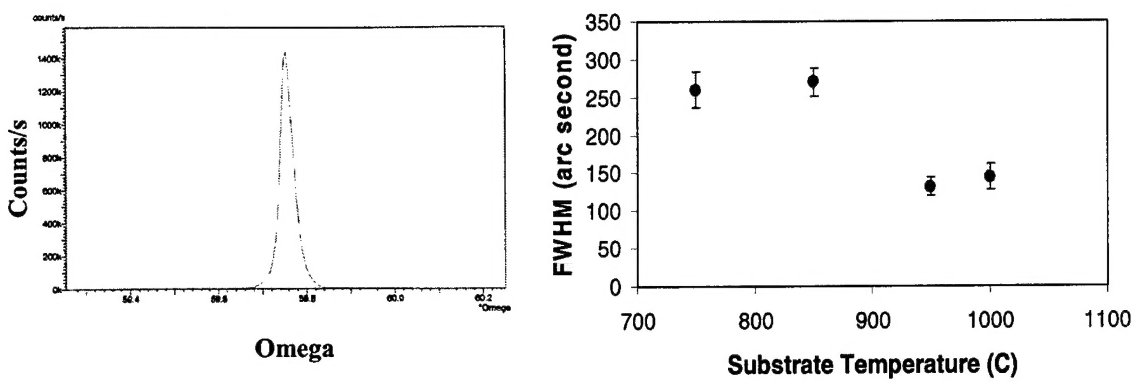


Figure 5: Schematic diagram of the Hot filament (HF) CVD method.

Figure 6(a) shows the (004) X-ray rocking curve obtained from homoepitaxial diamond film deposited on a large type Ib crystal using standard deposition conditions. The FWHM of the (004) rocking curve is approximately 120 arc seconds which is comparable to the FWHM of diamond substrates (approx. 112 arc seconds). The FWHM of homoepitaxial diamond films as a function of the deposition temperature is shown in Figure 6(b). The figure shows that the optimum deposition temperature for homoepitaxial diamond growth is approximately 900 –1000 °C. Extensive Raman studies were conducted on homoepitaxial diamond films. The Raman spectra from a diamond are observed at 1332 cm^{-1}. In microRaman spectroscopy, a microscope is used to focus the laser to small spot (1-100 microns). The Raman data was collected using an excitation wavelength of 514.5 nm. The FWHM of the 1332 diamond peaks provides an insight into the crystalline quality of diamond. Also the Raman peaks in the 1500 cm-1 region provide information if some non diamond graphitic peaks are present in the sample. Figure 7 (a) shows a typical diamond spectra obtained from a 1 micron diamond film on Type Ib diamond substrates. The spectra show only the presence of the diamond Raman peak and absence of any other graphitic peaks. This clearly suggests the formation of the high quality diamond films on homoepitaxial substrates. The FWHM of the Raman peaks as function of deposition temperature is shown in the figure. The location as well the FWHM of the 1332 Raman peak is controlled by the processing conditions. The shift in the Raman peak is an indication of the stresses in the diamond film. One typically observes two types of stresses during the growth of diamond films. (i) Intrinsic growth stresses and (ii) thermal stresses due to thermal coefficient mismatch between the film and the substrate. As the diamond substrate and the diamond film we do not expect any thermal stresses to develop in the system. However, several mechanisms are expected to generate the intrinsic stress including the incorporation of impurities and gases and the mosaicity of the films. The 1332 Raman peak location was found not to vary much during the growth process. Raman data (Figure 7(b)) also suggested temperature of 900 – 950 °C for optimum diamond deposition. These results corroborate the X-ray diffraction measurements.



(a) (b)

Figure 6: (a) (004) rocking curve obtained from homoepitaxial diamond film and (b) the variation in FWHM rocking curve widths as a function of deposition temperature.

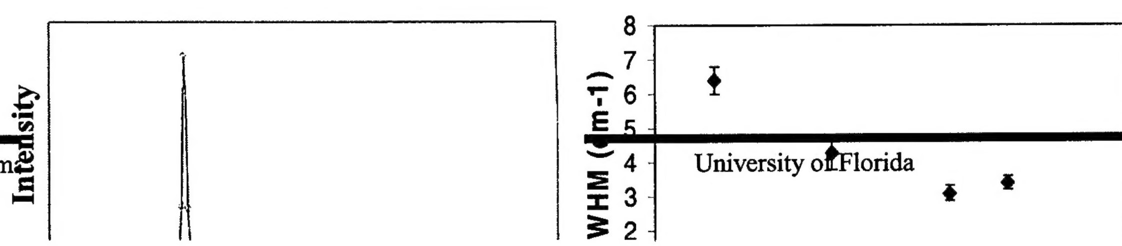
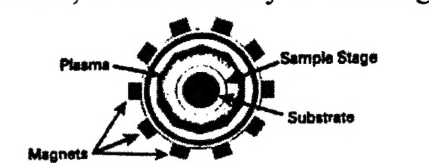


Figure 7: (a) typical Raman spectra obtained from homoepitaxial film and (b) the variation in FWHM of the diamond peak in Raman spectra as a function of the deposition temperature.

Task III. Electronic Processing of Single Crystal Diamond

To make electronic and optoelectronic diamond devices, it is necessary to investigate electronics processing of diamond films. In the Phase I, we conducted three studies (i) gas phase etching of single crystal diamond films, (ii) preliminary ion implantation studies and SIMS studies to determine the defects in the films. Both these processes are summarized. The diamond etching studies were conducted using and oxygen ECR (electron cyclotron plasma) system. Figure 8 shows a schematic diagram of the ECR plasma system. Briefly the oxygen gas is broken down into its ionic species by the use of the ECR system. The positive ions are attracted to the diamond substrates which are negatively charged due to RF biasing. The etching rate of the diamond crystals is dependent on the oxygen partial pressure, the microwave power and the angle of incline of the substrate. The etching rates of diamond can be increased by increasing the oxygen partial pressure, microwave power, and using normal incidence (see Figure 9(a) and 9(b)). It should be noted that under oblique incident the surface of the diamond film can be planarized. The use of oxygen plasma to etch diamond films opens the possibility of using silica based films for diamond patterning purposes. The silica films are expected to a have very low removal rates for oxygen plasma based



Top view of ECR module showing magnet ring configuration.

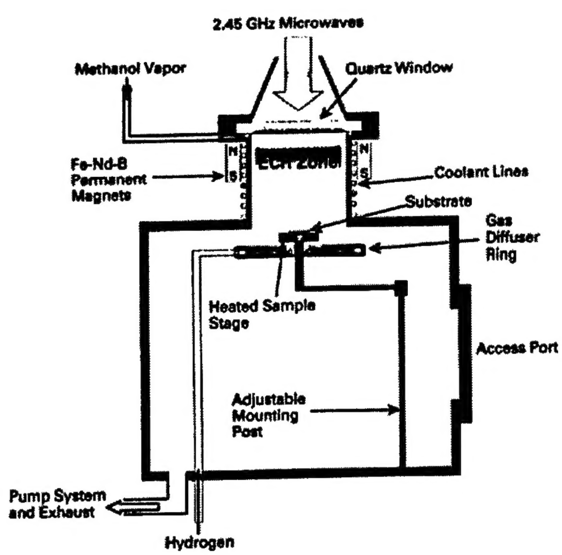


Figure 8: Schematic diagram of the ECR plasma system to conduct oxygen etching of diamond film.

removal, thus providing a high selectivity for patterning of diamond films for fabrication of optoelectronic devices.

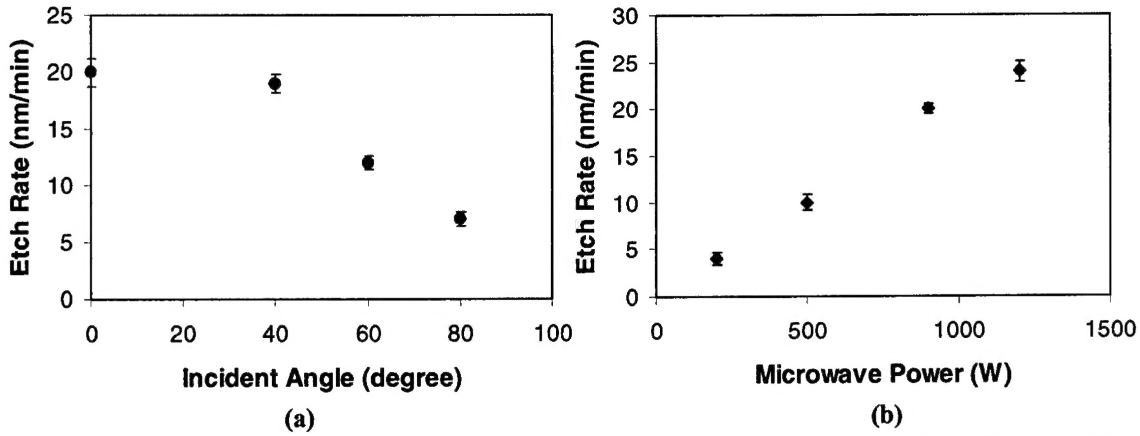


Figure 9: The etch rate of diamond film in an oxygen ECR plasma as a function of angle of incidence and microwave power. The pressure in the system is approximately 50 mTorr of oxygen.

Preliminary ion implantation studies and impurity incorporation studies have also been conducted. The impurity concentrations in the Type Ib single crystals were measured using standard SIMS measurements. Table 2 shows the typical concentration obtained using SIMS. Significant impurities of Re and Mo were observed in the homoepitaxial diamond films (Figure 10(a)). We attribute these to the very high filament and substrate temperatures in the HFCVD system. To conduct controlled dopant studies (Phase II of project), SIMS experiments were conducted by the University of Florida to quantify boron and phosphorous concentrations. Figure 10(b) shows the calibration implants of boron in the diamond crystal. Such calibration studies will be useful in the Phase II of this project.

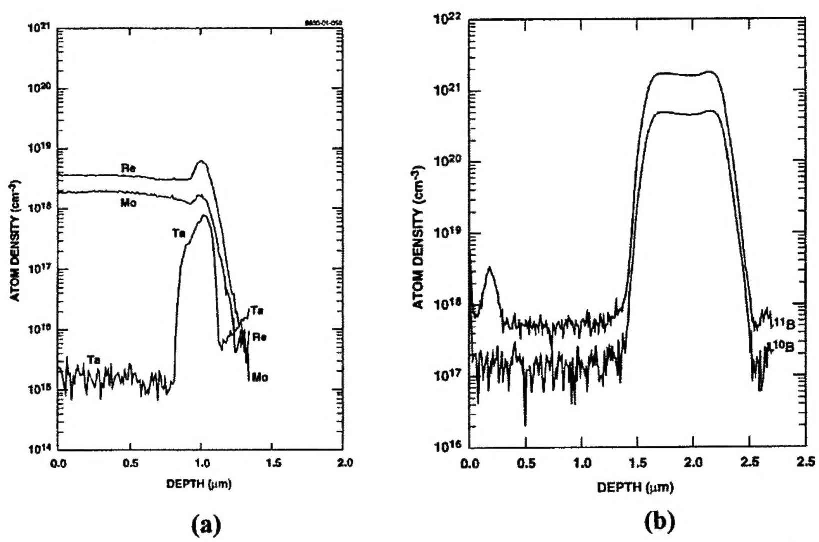


Figure 10: (a) SIMS spectra show the impurity concentrations in a diamond CVD films and (b) SIMS studies to quantify the amount of Boron in the diamond film. Boron Ion implantation studies were conducted to quantify the dopant incorporation.

Task IV. Investigation of Diamond Electronics Based on Single Crystal Diamonds:

The goal of this task was to evaluate the ability to make optoelectronics devices based on single crystal diamond substrates. In the Phase I of this STTR project, we have developed the infrastructure to synthesize, pattern, process and measure the properties of electronic quality diamond crystals. We plan to further develop and apply this knowledge in fabrication of usable electronic devices. Based on our internal assessment three possibilities for diamond based electronic devices exist. They include (i) solar blind UV (< 320 nm) detectors using uncompensated type A based defects in natural diamonds, (ii) Solar Blind UV detectors based on Homoepitaxial Synthetic Substrate Diamond technology, and (iii) Diamond LEDs. A summary of each of the applications is described below;

(A) Solar Blind UV detectors using uncompensated type A type based defects in natural diamonds. Diamond has long been known as a versatile material for solar blind detectors operating from ultraviolet (UV), vacuum ultraviolet (VUV) to X-ray and gamma regions of the electromagnetic spectrum. Applications within satellite technology and military hardware could all benefit from a robust, radiation hard solid state detector which is highly discriminating between UV and visible light. The wide bad-gap of diamond combined with its high carrier mobilities, saturated electron velocities, electric field breakdown strength, resistivity, thermal conductivity and mechanical strength of ideal diamond makes it the most sought after materials for these applications. These properties make diamond extremely attractive for the realization of detectors able to operate in extreme environments such as space and high temperature. Working closely with various scientists across the globe and using the processing techniques developed in the course of this research such solar blind detectors can be built. These detectors are sensitive in the 280 nm to 320 nm range because they operate on the optical activation of A type defects found in natural diamond. The detectors are also expected to be insensitive to UV A band (320 nm to 400 nm), and optical wavelengths, thus making it very useful for military applications.

(B) Solar Blind UV detectors based on Homoepitaxial Synthetic Substrate Diamond Technology: Alternatively, the solar blind UV detectors can be made from high quality homoepitaxial diamond. Using this process, we can produce of large (> 1cm x cm) diamond, single crystals, with low impurities, and low dislocation densities (< 100 cm^{-2}), using a commercially feasible process would perhaps represent a significant advancement for development of radiation hard, and robust UV detectors operating in hostile environments.

(C)Diamond LEDs: The wide energy gap of diamond is attractive for optoelectronic applications because it allows the possibility of deep ultraviolet (DUV) light emitting devices. Diamond based light emitting diodes can be used as compact, efficient DUV sources for wide variety of applications including white light generation, remote sensing and related applications. The high thermal conductivity, hardness and chemical inertness of diamond also may offer the possibility for efficient electrical pumping without significant thermal rise.

As all these optoelectronics devices require high quality tailored substrates, diamond growth and processing capabilities. Sinmat with its partners (University of Florida, Gemesis Inc) has the necessary qualifications. We plans to focus our effort in Phase II in developing diamond based optoelectronic devices.

4.0 Project Milestones and Timelines:

An outline of the proposed tasks and milestones for the Phase I STTR proposal is shown in Table 3. The table also shows the time-line for other tasks we plan to conduct during the Phase II of this project. As noted in the project summary we were able to successfully complete all the projects tasks within the Phase I time-frame of this project.

Table 3: Timeline of various Tasks

Phase I	Months				Phase II
	0	2	4	6	
Evaluation of large single crystal diamond substrates	**X**	**X**			
Diamond CVD growth system set-up and Growth	**X**	**X**	**X**		
Evaluation of properties for diamond films		**X**	**X**	**X**	
Patterning and Contact Studies					**X**
Controlled Doping of Diamond Studies					**X**
Diamond LED fabrication					**X**
Evaluation of diamond LED characteristics					**X**

5.0 Future Plans and Proposed Phase II Research Effort:

During the Phase II effort, working in concert with Gemesis Inc (A. Novikov) and Prof Steve Pearton (University of Florida) who is an expert in wide band gap semiconductor device processing, we plan to focus our effort on the commercialization of diamond based devices. The nature and type of devices we plan to pursue in the Phase II research have been outlined in earlier section. Some of the issues we plan to study include:

Optimization of Diamond Growth : Further studies on optimization of diamond growth will be conducted. The studies will include the ensure deposition of a high quality , defect free film on large Type 1b diamond substrates. An important aspect of this research will be to reduce the impurity concentration in the films. The impurities are mainly due to the filament and holder in the HFCVD system that is exposed to high temperature. We plan to use the microwave plasma system to reduce the impurity concentrations.

Doping, and Electronic Processing Studies: The focus of the Phase II effort will shift to fabrication and commercialization of single crystal diamond devices. Doping studies using in-situ deposition techniques will be initiated in the Phase II of this project. Both p and n doping studies will be conducted in this research. These dopant activation studies will be measured

using Hall measurements, channeling RBS and SIMS measurements. Ohmic contact and patterning experiments will also be conducted.

Fabrication and Optimization of Single Crystal Diamond Devices: As the important goal of the Phase I research was to make large high quality defect and impurity free homoepitaxial films. These materials will be used to fabricate optoelectronic devices. These devices will be compared with single crystal devices made from specifically chosen natural single crystals such as solar blind UV detectors based on A type defects).

Commercialization of Diamond Based Devices: The commercialization of UV based devices will be explored. Some of the possible non-military applications include (i) uv detectors to determine exposure to harmful UVB radiation, (ii) UV LED sources for fluorescence studies. More details will be submitted as a part of the commercialization plan.

6.0 Cost Expenditures

The details costs expenditures of various persons working on this project (Deepika Singh, R. Singh, technician) has been already been submitted and provided below. The PI and project participant traveled to National Technology Transfer Conference in Washington DC (Jan 2003) to determine strategies for commercialization of this technology. The University of Florida has been provided with $21,000 for their research costs on this project. There are no funds remaining as of report date.

Name	Manhours allotted	Manhours left	Total direct costs
Deepika Singh	175	0	8,750.0
Rajiv Singh	30	0	1,500.0
Technician	80	0	2,000.00

Item	Cost allotted	Expenditures Incurred
Direct materials	10,000	10,000
Travel	1,500	1,500
Fringe	3,675	3,675
Indirect Costs	14,816	14,816
University of Florida	21,000	21,000

Table 4: Summary of research budget allocations and expenditures incurred

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8.0 Appendixes None